

Costing at the Speed of Light: How a Concurrent Engineering Team Can Bootstrap Your Estimation Capabilities



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Background/Overview

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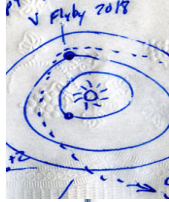
- What do you do when it is necessary to generate reasonable cost estimates at the earliest Concept Maturity Levels and you have never flown any similar missions before?
- At JPL we take advantage of the extensive amount of cost and technical data produced and archived by our Concurrent Engineering (CE) team, Team X to expand our data frontiers and cost modelling capabilities
 - Each year JPL submits 50 or more proposals and conducts hundreds of studies many in our (CE) environment



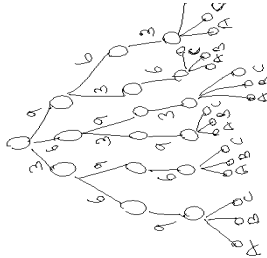
Concept Maturity Levels

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Cocktail Napkin



Trade Space



Baseline Concept



Preliminary
Implementation
Baseline



Step 1
Proposal

Step 2
Proposal

PDR

CML 1

CML 2

CML 3

CML 4

CML 5

CML 6

CML 7

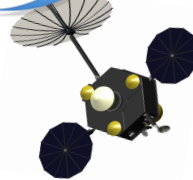
CML 8



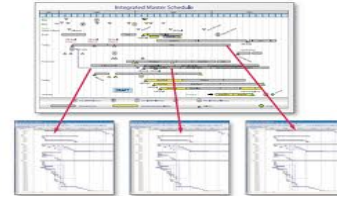
Concurrent
Engineering has
demonstrated a
major role here

$F=ma$

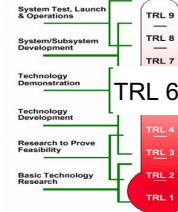
Initial Feasibility



Point Design



Integrated Concept

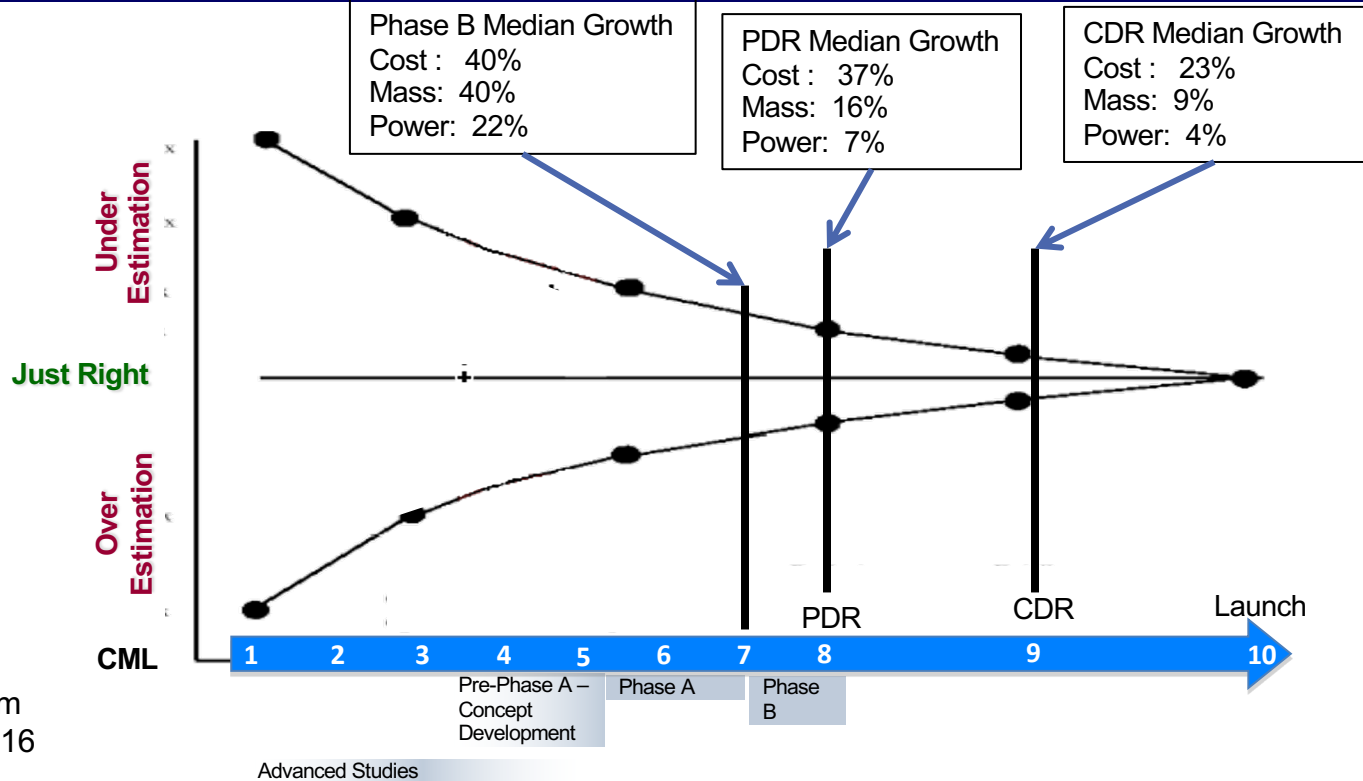


Integrated
Baseline



CML Levels and The Cone of Uncertainty

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Growth figures from
Hayhurst et.al., 2016
NASA Cost
Symposium

As design matures uncertainty reduces
across all technical and cost parameters



What is Concurrent Engineering?

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- Concurrent Engineering is a systematic approach by diverse specialists collaborating simultaneously in a shared environment, real or virtual, to yield an integrated design
- This approach is intended to cause the developers from the very outset to consider
 - All elements of the product life cycle, from conception to disposal, including cost, schedule, quality and user requirements

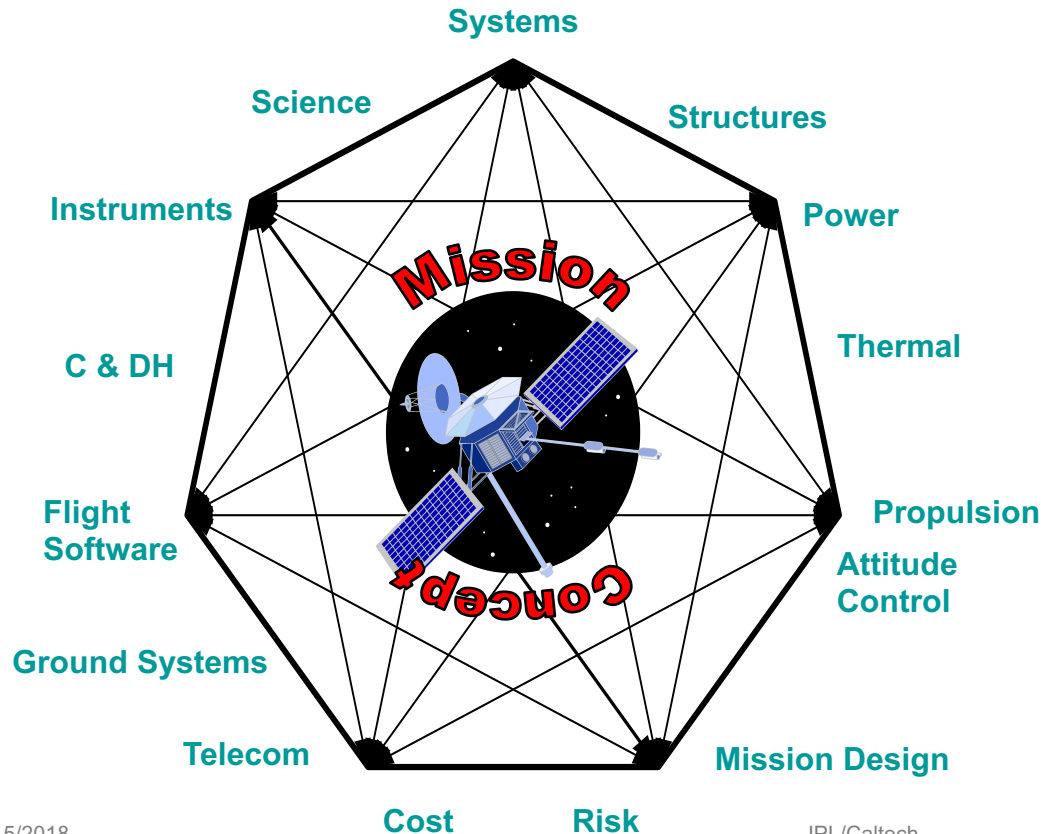


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JPL Institutional Cost Models

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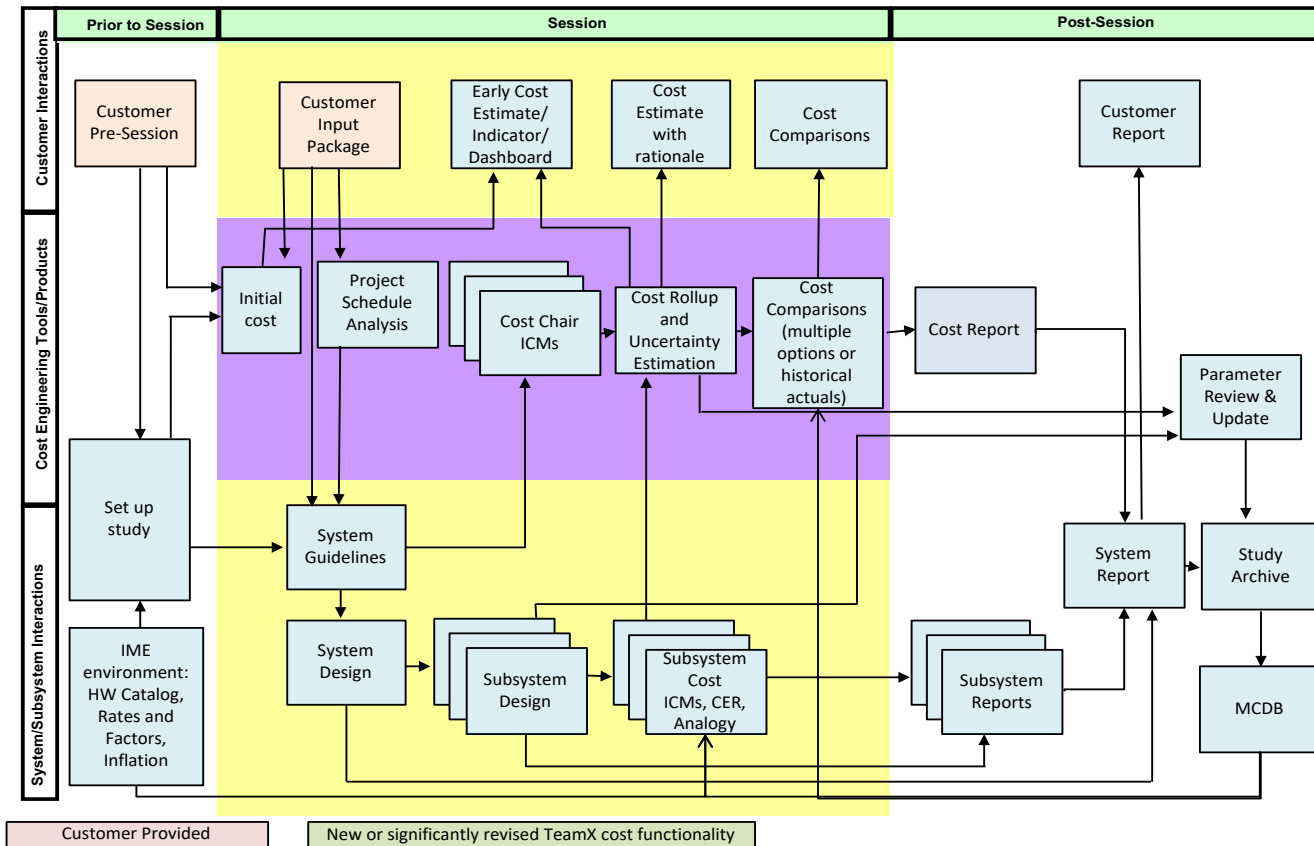


- Team X has always generated cost estimates during the sessions so design and cost can be traded off
- In the future we want to estimate cost before a study starts



JPL Team X Design and Cost Process

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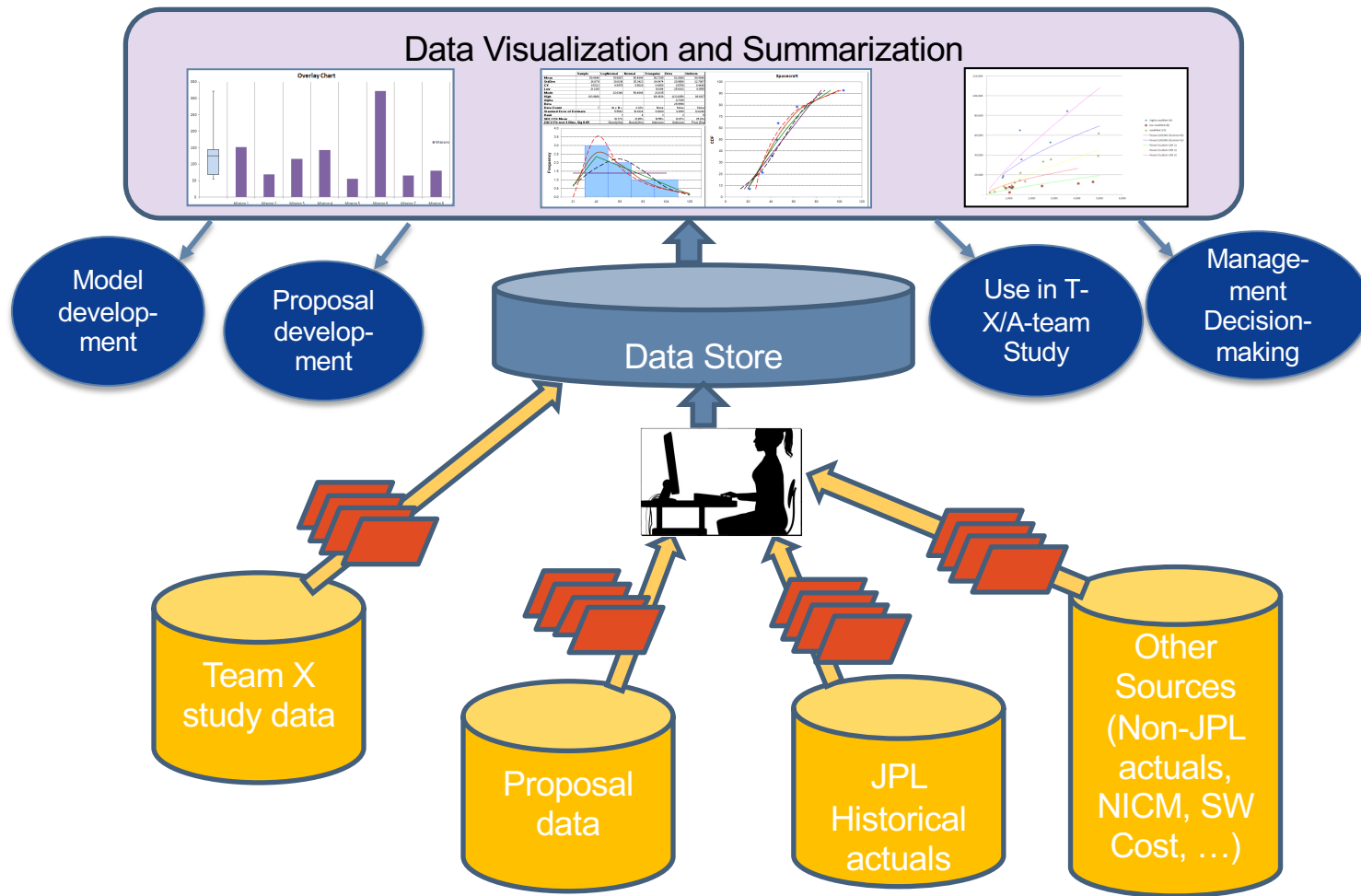
Why We Trust our CE Data

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- All ICMs are (re)validated on a periodic basis to evaluate the estimation error. The estimates are required to be within +/- 30% of the actuals.
 - In addition to verification testing, any model update must go through an extensive integration test before it is allowed to be used during a live session.
 - A Change Control Board (Cost CCB) is convened with members representing all of the engineering and science organizations. At the CCB, all of the results are presented and evaluated.
 - If any changes are made to the ICM, then the new model must be validated
- It is for these reasons that any cost estimates from Team X studies that are identified as containing sufficient valid information by the Cost Chair, Systems Chair and the Facilitator can be exported into the archival database for use in generating future estimates.



MCDB Architecture





Mission & Cost Database (MCDB)

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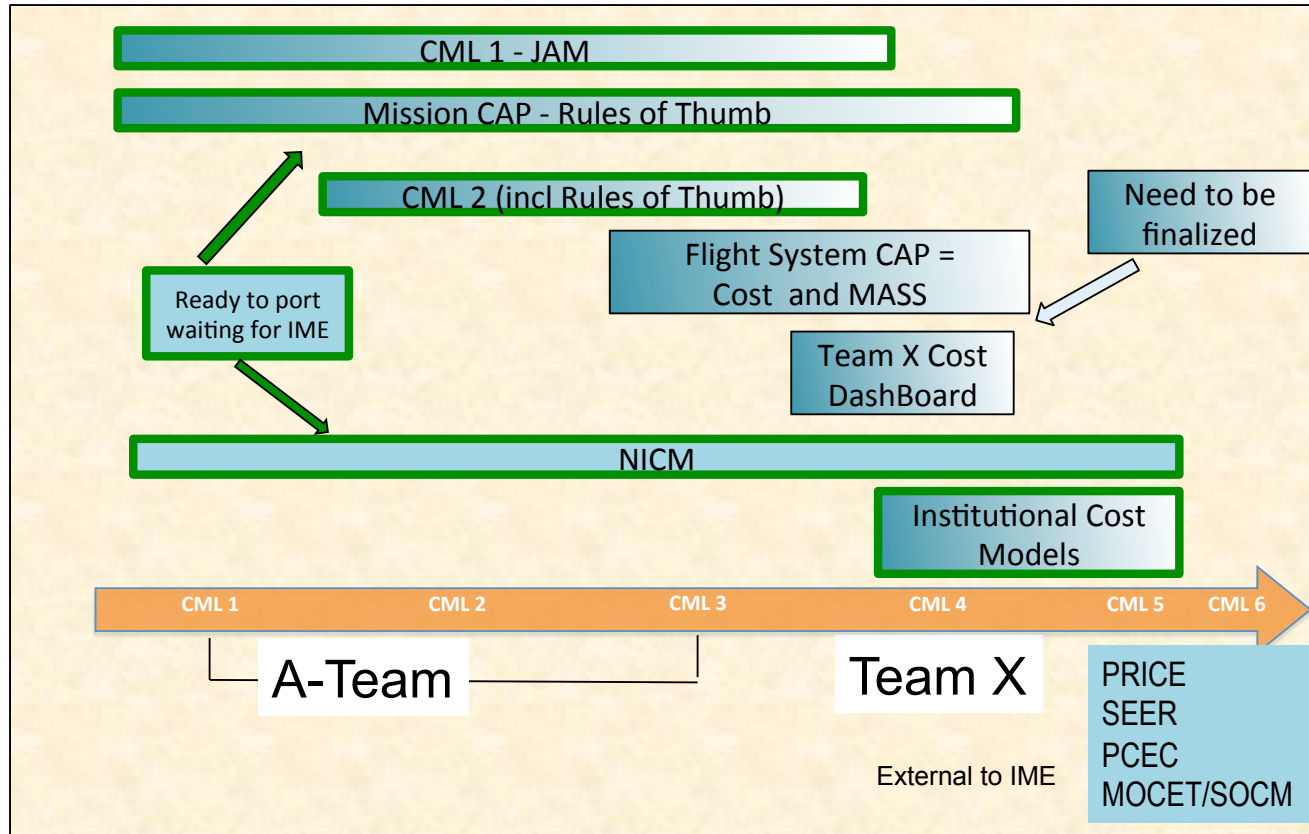
Data Sources

- JPL Historical Mission data from Historical Technical/Cost/Schedule Data Sheets
- Proposal data
- Team X mission study data
- Non-JPL actuals from the One NASA Cost Estimation (ONCE) (database version of the Cost Analysis Data Requirement (CADRe))
- Software costs from the Analogy Software Cost Tool (ASCoT)
- Commercial Bus Catalog – already in Hardware Catalog
- Team Xc cubesat study data
- Historical cubesat data from Cubesat Or Microsat Probabilistic and Analogies Cost Tool (COMPACT) database
- Historical instrument data from the NASA Instrument Cost Model (NICM) database



Different Cost Models for each Concept Maturity Level

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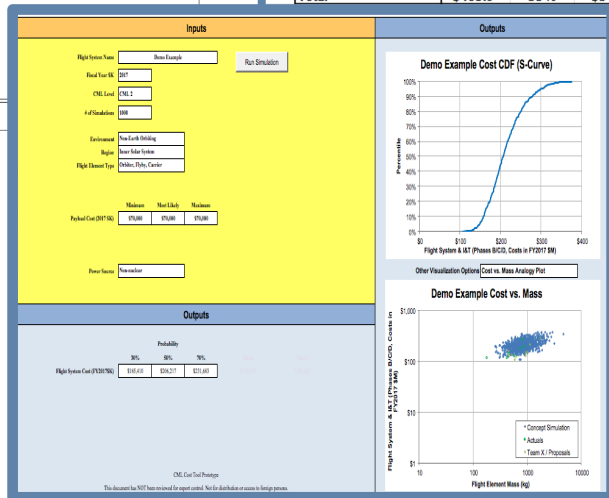


Figure 1: Flight System & BS Phases B/C/D, Costs vs. Weight

The top plot, titled "Demo Example Cost CDF (S-Curve)", shows the percentage of flight systems meeting or exceeding a cost threshold. The x-axis represents cost in millions of dollars (\$M), ranging from 0 to 6400. The y-axis represents the percentage, ranging from 0% to 100%. The curve starts at approximately 10% for costs up to \$100M, then rises steeply between \$200M and \$300M, and finally levels off at 100% for costs above \$400M.

The bottom plot, titled "Demo Example Cost vs. Mass", shows the relationship between flight system cost and weight. The x-axis represents flight system mass in kilograms (kg), ranging from 10 to 10,000. The y-axis represents flight system & BS phases B/C/D costs in millions of dollars (\$M), ranging from \$10 to \$1,000. The plot includes three data series: Concept Simulation (blue dots), Actuals (green dots), and Team K's Proposal (red dots). The Concept Simulation data points are clustered between 1,000 and 3,000 kg and \$100 to \$500M. The Actuals data points are clustered between 1,000 and 3,000 kg and \$100 to \$500M. The Team K's Proposal data points are clustered between 1,000 and 3,000 kg and \$100 to \$500M.

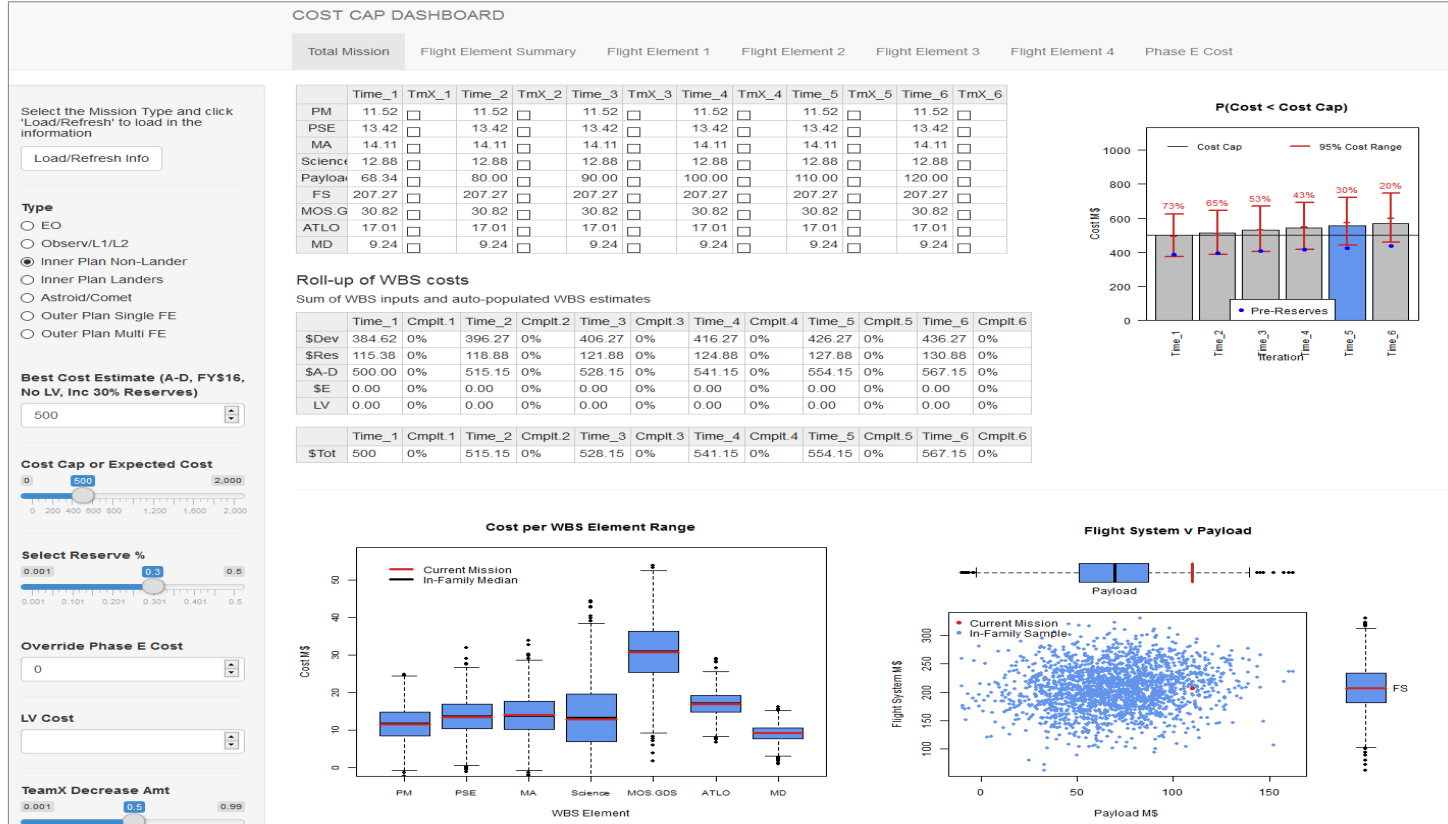
Data Shown is notional



Team X Cost Dash Board

Data Shown is notional

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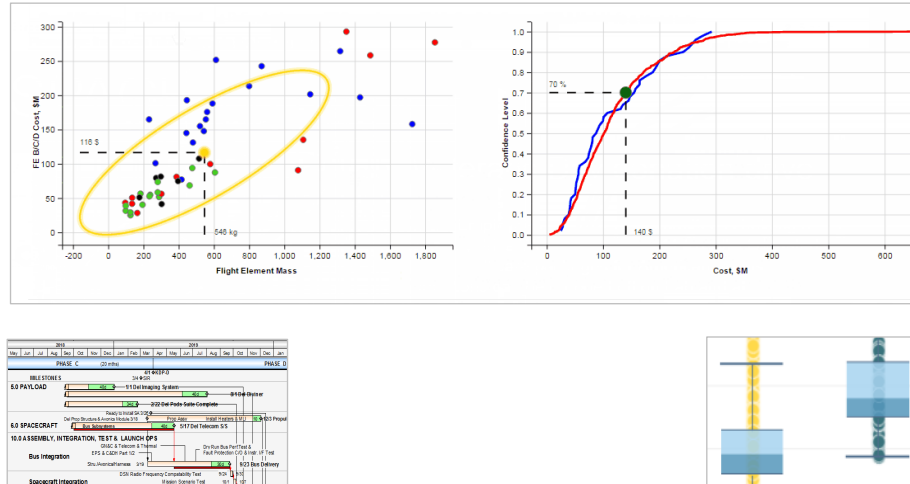




Mission & Cost Database (MCDB)

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Redefine cost engineering in formulation by facilitating credible and transparent cost estimation, schedule estimation, & risk identification early in a mission concept, enabling these parameters to influence design



Data Shown is notional



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